ment of that bureau, and of the intelligent interest of the Secretary of the Treasury and of the Chairman of the Committee on Coinage, Weights and Measures. And finally, but by no means least in importance, the successful outcome is due to the intelligent way in which this bill was placed by Mr. Stratton before the committees in the House and in the Senate. The enactment of such a measure ought to reassure scientific men in their judgment of the relation of Congress to legislation in such matters, since it shows that such legislation can be had without the help of any lobby, without the stimulus of personal interest on the part of Congress, if there is presented a clear and satisfactory reason for such legislation by those in whom Congressmen themselves have confidence.

Another feature of this bureau, which is unique, will also be watched by scientific men, as time goes on, with great interest, and that is the provision under which a visiting committee of five men, not connected with government service, report each year on the efficiency and needs of the bureau. I shall be greatly disappointed if this does not have a wholesome effect on the bureau itself, and on the relations of the bureau with Congress and with the department. It is scarcely possible that a Secretary of the Treasury will dismiss from office a competent head of the bureau who is supported courageously by this committee, nor will he appoint to the office of director a man whom they consider incompetent and unsuitable. If out of this relation there comes a wholesome criticism and a quickening of the scientific spirit, one may well hope that this feature may find a place in other departments of government scientific work.

HENRY S. PRITCHETT.

THE ASTRONOMICAL AND ASTROPHYSICAL SOCIETY OF AMERICA.

II.

The Constant of Aberration: C. L. DOOLITTLE.

For some time a revision of the latitude work carried on at the Sayre Observatory, Bethlehem, Pa., from 1876 to 1895, has been in progress with the view to its publication in a complete and final form. The first fasciculus of this publication appeared in the spring of 1901 and it is hoped that the remainder may be in form for the printer in the course of two or three months.

The present communication deals primarily with the value of the constant of aberration resulting from the series of observations extending from October 10, 1892, to December 27, 1893. A preliminary solution of the problem was published in the *Ast. Journal,* No. 406, 1897, which may be consulted for a fuller statement as to the method employed. The micrometer screw had become much worn by constant use for several years and the value was not constant throughout the series. Also the progressive errors which had been previously determined by means of Harkness' measuring engine were no longer applicable. It seemed very desirable that the screw value should be derived from the latitude observations themselves, but at the time spoken of the star declinations were not known with the requisite precision. For these reasons there was some hesitation as to the desirability of publishing the preliminary result, as it was thought possible that a considerable error might be involved. Recently a very careful discussion of the declinations has furnished the required data, and a result obtained which seems entirely free from the above named objections.

From the method of observing it is not possible to separate the correction to the aberration constant from the latitude vari-

ation without introducing an assumption with respect to one or the other. It has accordingly been assumed that the latitude variation can be represented by two periodic terms of 14 and 12 months, respectively. Each observed latitude, therefore, gives an equation of this form

$$x \sin N + y \cos N + z \sin \odot + u \cos \odot + E_\rho + T\mu + \Delta\phi + \phi_0 = \phi$$

where N is the 14-month term, E_ρ the correction to the aberration and T_μ secular change in the latitude.

The evening and morning observations furnish 1,744 and 1,052 equations of this form, respectively. These were solved retaining all terms. Then another solution was made excluding the annual term, as it is obvious that this can not be separated from the 14-month term in a series embracing a period of less than 16 months. The resulting value of the constant of aberration from both the preliminary and revised solution is as follows:

	Preliminary.	Revised Solution.
1st solution,	20″.552 ± .0095	20″.551 ± .0092
2d "	20 .555 ± .0093	20 .552 ± .0090

It thus appears that the suspected error in the preliminary reduction was a vanishing quantity.

Two other series of observations made at the Sayre Observatory have been employed for a similar investigation. The first, from December 1, 1889, to December 13, 1890, embracing 1,344 latitude determinations, was treated in a manner similar to that above described except that only one solution was made involving periodic term of 14 months. The resulting aberration constant is 20″.448 ± .014. It is doubtful whether this result is entitled to much confidence, the most serious objection being that the series does not cover a full term of 14 months, which is assumed for the period of latitude variation. The other series referred to extends from January 19, 1894, to August 19, 1895, the arrangement being that sometimes called the polygon method by which the aberration is obtained independently of the latitude variation. The result is 20″.537. Other recent determinations are given for comparison:

Flower Observatory.

1896–98	20″.580
1898–99	20 .542
1900–01	20 .560

J. W. J. A. Stein, Leiden—Zenith Telescope.

1899–1900 ....20″.541 ± .016

Albrecht—International Latitude.

20″.515

Chandler from Pond's Observations.

1825–36 ....20″.512 ± .019

The Period of Delta Equulei: W. J. HUSSEY.

Delta Equulei enjoys the distinction of having a period shorter by nearly half than that of any other visual double star and in being at the same time a spectroscopic binary. The latter characteristic is due to the visible components. It therefore forms a connection between the visual and spectroscopic double stars. This pair was discovered in 1852 by Otto Struve and observed by him occasionally for thirty years. Burnham's observations from 1880 to 1883, inclusive, appeared to indicate a period of 10.8 years; the elements subsequently derived by Wroublewsky and by See gave nearly 11.5 years. Between 1899.85 and 1900.65 the components rapidly approached each other and the apparent distance was extremely small at the latter date. This rapid change in distance is not explainable on the hypothesis that the period is nearly 11.5 years, but is entirely in accord with one of about half this length. The elements derived by the writer a year ago have a period of 5.7 years. From these elements he predicted that the components should separate to a measurable distance

this year and again close in. Observations show that this has happened. In July, 1901, the distance was approximately $0''.15$. It has now decreased to less than $0''.05$, or approximately the same as in the autumn of 1900. The data at present available appear to show that the period of 5.7 years is substantially correct.

The Duration of Twilight within the Tropics: S. I. Bailey.

The atmosphere renders many services to man. Not the least of these, perhaps, is the twilight. If there were no atmosphere, there would be no twilight, and the brightness of midday would be succeeded, the moment after sunset, by the darkness of midnight. Such a condition of affairs would cause considerable inconvenience. Twilight may be said to last until the last bit of illuminated sky disappears from the western horizon. In general it has been found that this occurs when the sun has sunk about 18° below the horizon. The duration of time which the sun takes in reaching this position is very different at different latitudes. At the North Pole one would have about six months of daylight, followed by nearly two months of decreasing twilight, followed in turn by more than two months of night. In summer, at latitudes greater than 50°, twilight lasts from sunset to sunrise. There is no night there, during this season. In the temperate zones the duration of twilight ranges from an hour and a half to more than two hours. Within the tropics the sun descends nearly or quite vertically; but even here the time required for the sun to reach a point 18° below the horizon is more than an hour. There seems to be no reason, therefore, in the general theory, for the widespread belief that the duration of the tropical twilight is extremely brief. This idea is found not only in current popular literature, but also in some of the best text-books on general astronomy. Young's 'General Astronomy,' p. 69, says: "At Quito and Lima it (the twilight) is said to last not more than twenty minutes." Why Quito should be classed with Lima I do not know, except that both are within the tropics. 'The Heavens Above,' by Gilbert and Rolfe, remarks: "Within the tropics, where the air is pure and dry, twilight sometimes lasts only fifteen minutes." Since Arequipa, Peru, lies within the tropics and has an elevation of 8,000 feet, and the air is especially pure and dry, the conditions appear to be exceptionally favorable for an extremely short twilight. On Sunday, June 25, 1899, the following observations were made at the Harvard Astronomical Station, which is situated there: The sun disappeared at 5:30 p.m., local mean time. At 6:00 p.m., 30 m. after sunset, I could read ordinary print with perfect ease. At 6:30 p.m. I could see the time readily by an ordinary watch. At 6:40 p.m., 70 m. after sunset, the illuminated western sky was still bright enough to cast a faint shadow of an opaque body on a white surface. At 6:50 p.m. the illumination was faint, and at 6:55 p.m., 1 h. and 25 m. after sunset, it had disappeared. On August 27, 1899, the following observations were made at Vincocaya. The latitude of this place is about 16° south, and the altitude 14,360 feet. Here it was possible to read coarse print 47 m. after sunset, and twilight could be seen for an hour and twelve minutes after the sun's disappearance. It appears, therefore, that while the tropical twilight is somewhat shorter than occurs elsewhere, and is still further lessened by favorable conditions, such as great altitude, and a specially pure air, it is never less, and generally much longer, than an hour.

The Determination of Double Star Orbits: George C. Comstock.

The usual data for the determination of

a double star orbit consist of a series of observed position angles and distances with the corresponding times of observation. From this data it is customary to derive the apparent orbit of the star by plotting the observed coordinates and drawing through the resulting points the best ellipse that can be fitted to them, subject to the condition that in this ellipse the radius vector must sweep over equal areas in equal times. The author knows no published statement showing how this condition is applied in the actual construction of the ellipse and it is not apparent how it can be applied in any satisfactory manner in this purely graphical process. Moreover, the process is open to the additional objection that it takes small account of the circumstance that of the three elements entering into a complete double star observation, position angle, distance and epoch, the time of observation is determined with a precision incomparably superior to that of the measured coordinates, and should therefore play a prominent part in the determination of the orbit instead of the subordinate rôle commonly assigned it. The method proposed for improving the current practice in these respects reverts to the practice introduced by Sir John Herschel, of plotting the observed position angles with the corresponding times as abscissæ, and extends the same practice to the observed distances. From the resulting curves data are derived for assumed epochs, and through a least square adjustment supplemented by mechanical quadratures are transformed into normal places that satisfy rigorously the condition of constant areal velocity. A partial control upon the character of the data and the treatment to which they have been subjected is furnished by the quasi rigorous condition that the adjusted normal places shall all lie upon some ellipse. In the adjustment of the data there is incidentally determined the areal velocity of the radius vector and this in connection with the apparent orbit, plotted from the normal places, leads immediately to a determination of the periodic time and to the independent determination of the dates of periastron and apastron passage. The agreement of the double interval between these dates with the periodic time first determined furnishes a partial check upon the work. The transition from the apparent to the real orbit may be made by any of the standard methods, but that of Klinkerfues when simplified by the introduction of the elements above derived is especially convenient. There was presented an application of the method above outlined to the determination of the orbit of Struve 2,107, showing that the labor involved does not greatly exceed that of the ordinary methods and is fully compensated by the checks furnished *en route* as well as by the increased precision of the results.

A Cosmic Cycle: FRANK W. VERY.

An application of a new doctrine of an explosive condition of matter (limited by composition, pressure and temperature) to various phenomena of the heavenly bodies, and to stellar evolution. Novæ are regarded as the culmination of long-enduring antecedent stages of stellar preparation, and as indicating (along with the helium stars) a condition of instability and active modification which is incompatible with planetary growth, but which is followed by other relatively quiescent stages favorable to the production of planets and to their orderly development. An extension of the doctrine of the conservation of energy is involved, and the problem of the sustentation of solar heat is approached from a new standpoint which admits of a great extension in the duration of the solar system, thus satisfying the demands of the geologist for a prolonged terrestrial

duration. (The paper will appear in full in the *American Journal of Science.*)

A Comparison of Printing and Recording Chronographs: C. S. HOWE.

A printing chronograph, to be of any value to astronomers, should be easily set and regulated; it should run several hours without any attention; it should have a small probable error; its results should agree, or differ by a constant amount each night, with the results from the recording chronograph. Several months' experience with the Hough printing chronograph at the Case Observatory shows that the instrument can be easily set and adjusted and that it runs several hours without any attention. The probable error of one record was found to be $\pm$ .011 seconds, and the probable error of the mean of nine wires $\pm$ .004 seconds. Similar tests with the recording chronograph give respectively $\pm$.006 and $\pm$.002 seconds. These errors are so small that they can be neglected. A direct comparison of the two chronographs showed an average difference between them of .025 seconds, the printing chronograph making the record first.

The Clock Room at the Case Observatory: C. S. HOWE and E. H. BROWN.

The clock room is a room built of tile within one of the rooms of the basement of the Physical Laboratory. The basement is warmed in the daytime, but not at night. The space outside the clock room is warmed by two gas stoves, the gas being turned on or off by an automatic burner which is regulated by a thermostat made of steel and hard rubber. This controls the temperature outside the clock room within one degree centigrade and inside the clock room within about one half degree. The inside temperature is further controlled by another thermostat, which by means of a relay throws in or out one or more electric lamps, the heat of which changes the temperature. This arrangement keeps the temperature within one tenth of a degree. The hourly rates of a Riefler clock, enclosed in a glass case from which the air is partially exhausted, were also given.

The Almucantar as an Instrument for the Determination of Time: C. S. HOWE.

In 1885 Dr. Chandler compared the clock corrections determined with a small almucantar with those determined with the large Transit Circle of the Harvard Observatory. The Case Almucantar is a large instrument with a six-inch object glass. It was not possible to compare it with a large transit and so its value for the determination of time could only be determined by the consistency of the several results obtained on any one night and by the excellent and nearly uniform clock rates determined by it. The differences between the several values of the clock corrections on any one night were usually not more than two or three hundredths of a second and the greatest difference since June, 1901, was 0.13 of a second.

A Description of the Second (Chile) Mills Spectrograph: W. W. CAMPBELL.

The mechanical features of the instrument and its method of support are radically different from those of the conventional spectrographs. The entire framework is composed of a single steel casting with webs and flanges bracing it thoroughly in every direction and with especial reference to the supports near its two ends. The slit, the prism box, the camera and the collimator and camera lenses are all fixed directly to the casting. A reflecting slit is used, curved to make the spectrum lines straight. The weight of the entire spectrograph is about 75 pounds. The instrument is mounted in a supporting cradle composed of tee and channel steel bars in such a way that it will rest on two points (a plane and a ring) near the two ends of

the instrument, respectively. Strains in the supporting cradle cannot induce strains in the spectrograph. The old method of supporting spectrographs entirely from one end, allowing the other end to project unsupported out into space, invites flexure effects, and it is hoped that the new method of support will prove to be a radical improvement. The whole spectrograph will be moved to bring the slit into the focus of the Cassegrain telescope. A temperature case similar to the one used for the past three years on the original Mills spectrograph will enclose the instrument.

On the Capture of Comets by Jupiter: PERCIVAL LOWELL.

This paper gave in diagrams a part of the author's memoir on the subject, not yet published, in which he explained the action of Jupiter upon a comet entering the planet's sphere of activity, and the relation borne by the direction and the speed of approach to the comet's subsequent behavior. The paper showed that Jupiter was not only capable of transforming at one encounter a parabolic comet into an elliptic one of about half his own major axis, but could actually cause a comet to make the planet instead of the sun the goal of its visit, and send it back again into space without circumnavigating the sun at all. The argument then developed a critical angle differentiating those comets which Jupiter's action might render retrograde from such as it could not. A table here showed that the angle of approach of each of the comets composing Jupiter's comet family not only at the present moment fell within the critical angle for each, but must do so for all time, abstraction made of perturbations by other bodies and the approximation being of the first order. In other words, that under these conditions the present direct motion of all the members of Jupiter's comet family was such in perpetuity. The planet might drive them off into space but could never render any of them retrograde.

The Latitude-Variation Observatory of the International Geodetic Association: HERMAN S. DAVIS.

A brief statement of the plan of the International Association in the establishment of the four stations at Gaithersburg, Maryland, Ukiah, California, and in Japan and Sardinia for a systematic and continuous series of observations for the study of variations of latitude. Particular attention was given to the two stations in the United States under the general direction of the Coast and Geodetic Survey, the one in charge of Dr. Schlesinger, at Ukiah, and the other in charge of the speaker, at Gaithersburg. Illustrations with the lantern were shown of both these stations with plans of the buildings and views of the telescope at Gaithersburg. Attention was called to the admirable quality of the observations made by Mr. Edwin Smith, who was in charge of the station at Gaithersburg prior to January, 1901, and entire credit given him for the erection of the buildings and installation of the instruments at this station, and to the active and enthusiastic support of the superintendent of the Coast Survey from the very inception of the plan to establish these stations in the United States.

Some Vices and Devices in Astronomical Computations: HERMAN S. DAVIS.

Owing to the briefness of the time requested for the presentation of this paper and the fact that a considerable portion of that time was devoted to the preceding paper which was presented by request—not being regularly on the program—the speaker gave only a meager description of some of the methods which he is now using in the new reduction of the 160,000 star-

observations made by Piazzi at Palermo between 1792 and 1813. Particular attention was directed to only one of the many devices which have been applied for shortening the computations whereby already the work is two years ahead of the schedule outlined at the beginning of the undertaking, that device being the use of specially constructed table of limiting-values instead of such logarithm or antilogarithm or other tables as appear in print. Illustrations of these special tables and their application and data as to the percentage of time saved by their use were also given. Another one of the devices has already been published in *Astronomical Journal*, No. 498 (XXI.: 143–4), and a number of others, of which mention was omitted for lack of time and the lantern slides which had been designed (but unexpectedly delayed) for their proper exposition will be put into print at some future date.

Observations of Meteors, November 13–16, 1901: J. K. REES.

As in previous years, I observed with Mr. Charles A. Post from his observatory at Bayport, Long Island. We arranged (1) to photograph meteor trails with four cameras mounted on the equatorial which was driven by an excellent clock, (2) to count the meteors and (3) to record individual meteors which exhibited striking peculiarities.

1. The equatorial and cameras employed are shown in Plate II., *Popular Astronomy* (No. 82), February, 1901.

The apertures and focal lengths are given in the following table:

Instrument.	Aperture.	Focal length.
Equatorial telescope.	6 inches.	90 inches.
Willard photographic doublet.	$5\frac{1}{2}$ "	23 "
Darlot portrait.	$1\frac{1}{2}$ "	$6\frac{1}{2}$ "
Anthony portrait.	3 "	$13\frac{1}{2}$ "
Goerz wide angle double anastigmatic.	$1\frac{1}{2}$ "	$9\frac{1}{2}$ "

PHOTOGRAPHIC EXPOSURES.

Nov. 13. 12:00 to 18:00 (Eastern Standard time). A number of experimental plates were taken but no effort was made to photograph meteors, as so few were seen.

Nov. 14. 11:20 to 12:24. Exposed the Goerz lens pointed at the belt of Orion. 13:15 to 14:05. Exposed all the cameras pointed as follows: Willard and Anthony lenses at Procyon, Goerz lens at belt of Orion, and Darlot lens at μ and ε Leonis. At 15:00 the sky clouded but cleared again at 15:30. 15:42 to 16:30 all cameras were exposed. The Willard and Anthony on ε Leonis, the Goerz on ζ, ε, δ Hydræ, and the Darlot on Ursa Major.

The clouds began to spread over the sky again, and in a short time it was impossible to see a star, later it cleared. Observers then confined their attention to counting and observing the meteors.

Nov. 15. 11:45 to 13:00. Exposed all cameras. Willard and Anthony lenses on Pollux, Goerz lens on Procyon, and Darlot lens on γ Geminorum. 14:35 to 15:45. Exposed all cameras. Willard and Anthony on ζ Leonis, Goerz on Regulus, and Darlot on λ and μ Leonis Minoris. Clock did not work as well as usual. 16:01 to 17:00. Willard lens was omitted. The other cameras were pointed as in the preceding exposure.

Mr. Post developed all the plates. The plates taken on November 14 show a number of trails. Quite a remarkable meteor trail is shown on the plates taken with the Willard and the Anthony lenses between 15:42 and 16:30. The notes given under 'Record of Individual Meteors' seem to show that this meteor appeared at 15:58.

2. Count of Meteors.

Only during the night of November 14 was any careful attempt made to count. Miss Edith Post and Miss Greenough observed the eastern sky looking toward the radiant. At first both observed the same part of the sky, but after 38 had been counted Miss Greenough observed the southeastern sky from the line from the radiant to the zenith, and Miss Post ob-

served the northeastern sky from the same line. The count was as follows:

Nov. 14. 12:15 to 13:40. Miss Post and Miss Greenough, 38; Miss Post—northeastern sky, 31; Miss Greenough—southeastern sky, 31. 13:40 to 14:20. Messrs. Post and Rees looking out of the opening in the roof of the Observatory toward the radiant, 20. 14:20 to 15:00. Miss Post—northeastern sky, 10; Miss Greenough, southeastern sky, 15. 15:50 to 17:55. The Misses Post and Greenough counted being assisted from 16:30 to 17:55 by Post and Rees. The total count of the four observers was 273. Total for the evening, 418.

Nov. 15. Post and Rees assisted by Mr. Post's 'handy man' counted, while engaged on the photographic work and looking out of the observatory opening, as follows: 11:45 to 13:00. 25, several of which were non-Leonids. 14:35 to 15:45. 3 of which 1 non-Leonid. 16:01 to 17:00. 23, several non-Leonids.

Nov. 16. 12:00 to 17:00. Looked out frequently but saw so few that no record was kept.

3. Individual Meteors.

Nov. 14. 11:30. Two bright Leonids—trails yellow-red 10° long—width very distinct. 11:51. Leonid from Procyon to θ Orionis—blue streak. 12:07. From star above Procyon to 'yardstick'—trail 25° long—lasted several seconds—yellow—Leonid. 12:10. Leonid through Ursa Major—bright trail. 12:15. Leonid through Ursa Major. 12:17. Leonid through Auriga. 13:18. Brilliant Leonid, near radiant—very small trail—orange color—bright as Mars at best. 13:27. Fine Leonid from Leo to zenith—trail 30° long—yellow-red. 13:30. Leonid through Ursa Major—fine. 13:40. Meteor near Procyon—from zenith down—short trail. 13:44. Fine Leonid through bowl of dipper—trail 5°. 13:51. Leonid under Procyon—8° trail—yellow-red. 15:58. Brilliant Leonid—trail 5°—lasted twenty seconds—blue-white—1st magnitude. 16:04. Leonid under Procyon—blue-white—10° trail. 17:28. Two brilliant meteors visible at same time—trails crossed—bright heads. One came from radiant and passed near α and β Can. Ven.—trail 30° long and lasted several seconds. The second seemed to come from below β Leonis and cut the trail of the first under Canes Venatici —trail 30°. Magnitude of each—2.

Nov. 15. 14:52. Bright Leonid under Leo Minor. 15:37. Leonid bright as Jupiter—in sickle—blue and red trail. About 15:55. Fire ball below Leo came from Orion. 16:10. From zenith through Leo Minor (λ and μ)—long train 40°. About 17:00. The zodiacal light showed itself in a grandly beautiful manner.

A Theorem concerning the Method of Least Squares: HAROLD JACOBY.

The following theorem and conclusion are doubtless well known to many astronomers, but the writer has not found an explicit statement of them in print. Let there be given two series of observation equations as follows:

$$\left.\begin{array}{l} a_1x + b_1y + c_1z + \cdots + n_1 = 0 \\ a_2x + b_2y + c_2z + \cdots + n_2 = 0 \\ \quad\vdots \qquad\quad \vdots \end{array}\right\} \quad (1)$$

$$\left.\begin{array}{l} a_1x + b_1y + c_1z + \cdots + p_1w + \cdots + n_1 = 0 \\ a_2x + b_2y + c_2z + \cdots + p_2w + \cdots + n_2 = 0 \\ \quad\vdots \qquad\quad \vdots \end{array}\right\} \quad (2)$$

the equations being identical in the two series except for the addition of one or more new unknowns, w, . . . in (2). Let each series of equations be solved by the method of least squares, and let $[vv]_1$ be the sum of the squares of the residuals resulting from the solution of equations (1), $[vv]_2$ be the sum of the squares of the residuals resulting from the solution of equations (2); then, no matter what may be the law of the coefficients $p_1, p_2, \ldots$, and even if these coefficients are assigned at random, $[vv]_1$ is always larger than $[vv]_2$.

Corollary.—The theorem can be extended easily to an additional case of equal importance. Instead of introducing the new unknowns w, . . . , by adding them to those already occurring in equations (1), we may select out certain equations from the series (1), and simply substitute new unknowns, like w, for old ones, like z, leaving the coefficients unchanged.

Conclusion.—The method of least squares is used ordinarily to adjust series of observation equations so as to obtain the most probable values of the unknowns. But

there is a subtler and perhaps more important use of the method; when it is employed to decide which of two hypothetical theories has the greater probability of really being a law of nature; or to decide between two methods of reducing observations. Cases abound in astronomy where the method of least squares is used for this purpose. It has been so employed, for instance, to decide whether stellar parallax observations should be reduced with equations involving terms depending on atmospheric dispersion, and terms depending on the hour-angle, to ascertain whether portable transit observations should be reduced on the supposition of a change of azimuth on reversal of the instrument (an application of the corollary), etc.

In such cases, astronomers not infrequently give preference to the solution which brings out the smallest value of [*vv*], the sum of the squared residuals. But in the light of the above theorem, it becomes clear that the mere diminution of [*vv*], alone is insufficient to decide between two solutions, when one involves more unknowns than the other. To give preference to the second solution it is necessary that the diminution of [*vv*] be quite large, and that the additional unknowns possess a decided *a priori* probability of having a real existence.

The Nebula about Nova Persei, 1901: FRANK W. VERY.

The rapidly shifting and fast fading nebulosity around the new star is regarded as an evanescent phenomenon comparable to the tail of a comet. Velocities of propagation of different orders are surmised, but as there is no known motion of material particles, even when of the dimensions of negative ions, swifter than that of light, the latter may be taken as a limiting value of velocity, from which it is deduced that the distance of the nova can not exceed 750,000,000,000,000 miles, an estimate which gives us a first approximation to the distance of the Milky Way, since the novæ all belong to the galactic stream. An explanation of the meaning of the complex structure of the hydrogen bands in the spectrum of the nova is given, and a further cometary analogy is shown through the existence of concentric spherical envelopes near the star, resembling comæ, which are inferred from the structure of the spectral bands. From the spectral variations attending the formation and motion of these envelopes, the mass of the star is concluded to be about 1,150 times that of the sun; and as this mass does not appear to have been appreciably changed in the first month, in spite of the enormous outpourings of hot gases, it follows that the luminosity of the star is not conditioned by the mass or by the state of the star's internal activity; and it is suggested that the brightness of the star's continuous spectrum depends upon the formation or dissolution of clouds of cosmic dust in the spaces immediately surrounding the nova.

A Short and General Method of Determining Orbits from Three Observations: A. O. LEUSCHNER.

The method is principally intended to aid in the rapid determination of an orbit from three observations, made at short intervals. It is essentially an improvement on Harzer's modification of Laplace's method contained in Méc. cél. T. I., première partie, livre II., Chap. IV. The first part of the paper deals with the discussion or Harzer's method. The modifications introduced by the author consist in: (1) The restriction of the number of observations to three, the minimum number necessary for the solution of the problem. (2) The reduction of the number of fundamental data to be approximated. In Harzer's method the fundamental data to be ap-

proximated are the heliocentric coordinates and their velocities, while in the present method they are the geocentric distance and the velocities of the heliocentric coordinates, all for the zero date. (3) A short method of obtaining preliminary values of the geocentric velocities and accelerations at the zero date. (4) A direct solution of the fundamental equation of the seventh degree in ρ_0, on the basis of von Oppolzer's table XIIIa ('Bahnbestimmung,' Vol. I.). (5) Differential formulæ for the determination of the final values of the heliocentric coordinates and velocities from which the elements are computed by Encke's formulæ. Chief among the advantages of the method here outlined are the ease with which such corrections to ρ_0, x_0', y_0', z_0' may be determined as will cause the residuals due to the original values of these quantities to disappear, and the possibility of determining these corrections directly from the residuals. On that account, it is of no great consequence if the originally adopted velocities and accelerations in α and δ are only approximate.

Elements of Asteroid 1900 GA and its Ephemeris for the Opposition of 1901–1902: A. O. LEUSCHNER and ADELAIDE M. HOBE.

This asteroid was discovered June 28, 1900, by the late director, James E. Keeler, of Lick Observatory, while photographing the region of the sky near Saturn with the Crossley Reflector. Trails were photographed on four days and point-images on two of these days. The problem of determining the orbit of the asteroid presents many points of interest and has led to the derivation of the 'Short and General Method of Determining Orbits from Three Observations.' The existing methods for determining orbits could not be used to advantage in this case, but the solution was successfully accomplished by means of the 'Short and General Method of Determining Orbits from Three Observations' outlined above. The magnitude of the asteroid at the present opposition (1902, Jan. 4) is 19.5 ± .75. The asteroid is, therefore, the faintest so far observed. The paper concludes with the discussion of the residuals of the measured positions of the termini of the trails relatively to the middle of the trails.

Discovery of Motion in the Faint Nebula Surrounding Nova Persei: C. D. PERRINE.

Early in the apparition of the new star in Perseus, short exposure photographs of it were secured with the Crossley Reflector by Messrs. H. K. Palmer and C. G. Dall. The first long exposure was secured on the nights of November 7 and 8. This negative had a total exposure of 7 h. 19 m. It was developed on the 9th, but owing to stormy weather was not dry and was not carefully examined until the morning of the 10th, when it was compared with the reproduction of a negative taken at the Yerkes Observatory on September 20 by Mr. Ritchey and published in the October number of the *Astrophysical Journal,* and the discovery at once made that several of the principal condensations in the nebula had moved to the southeast over a minute of arc in the interval. The main facts were embodied in a telegram which was sent to the Harvard College Observatory, for distribution to all observatories, at noon of November 10. A negative was obtained on the nights of November 12 and 13 with a total exposure of ten hours. A more rapid plate was used than on November 7 and 8 and with the longer exposure considerably more detail is shown. An exposure of 5 h. 28 m. was obtained on the night of December 4. As a storm came on, this plate was developed the following day. Considerable detail was shown on the negative and three

of the condensations were seen to have moved appreciably, while the strong one nearest the Nova showed but little if any change. An exposure of ten hours was secured on the nights of December 8 and 11, the 9th and 10th being cloudy. The motion of the nebula is so rapid that even in this interval of three days, blurring in the best-marked condensation is noticeable. A comparison of the last negative with that of November 12 and 13 reveals a number of changes. Condensations *A*, *B* and *C* (Lick Observatory Bulletin No. 10) have each continued their motions to the southeast full ½′. Condensation *D* shows little or no change. Perhaps it is moving nearly in the line of sight. The negatives of December 4 and 8–11 show two new wisps of nebulosity southwest of the Nova at distances of 13′ and 14′, respectively. They are approximately arcs of circles of which Nova is the center and are about 2′ in length. They have been carefully looked for on the November negatives, but no traces are there found of them. Throughout the entire southeast quadrant faint nebulosity is shown to a distance of 18′ on the negative of December 8–11. There is but little appearance of structure in this outlying nebulosity. Several wisps of nebulosity 6′ to the north of Nova are sufficiently strong to show that motions outward of ¼′ to ½′ have taken place in the interval of 27 days. A wisp 9′ to the north has also moved outward full ½′. 6′ to the northwest of Nova is a wisp which has moved outward ¼′. None of these wisps to the north and northwest are well enough defined lengthwise to make the other component of motion certain in the interval. Directly to the west is an arrow-shaped mass of nebulosity resembling somewhat the structure of condensation *A*. It has certainly moved outward and there appears to have been a motion to the northwest. Many changes of form and intensity of masses of nebulosity have been noticed other than those referred to above, but which can not well be described. A longer series of photographs is necessary to deduce the character and amount of motion of these fainter masses. Lantern slides of the various photographs secured with the Crossley reflector were exhibited.

A Determination of the Wave Lengths of the Brighter Nebular Lines: W. H. Wright.

In the progress of our investigations upon the spectrum of Nova Persei (see Lick Observatory Bulletin No. 8) there arose the necessity for a more accurate knowledge than then existed of the wave lengths of the Brighter Nebular lines. The spectra of the Orion Nebula and of three of the brighter planetary nebulæ have been photographed in some cases with one prism, and in other cases with three prisms, and the resulting plates have been measured and reduced. The wave lengths of 16 bright lines have been determined with considerable accuracy, the fifth significant figure being determined definitely for the principal ones, and the uncertainty in the sixth place for the brighter lines being comparatively small. A slight correction appears to be needed in the values at present accepted for the positions of the two chief nebular lines determined by visual means. In the course of the work three new nebular lines have been discovered. The well-known lines usually described as H_ϵ and λ 3,727 have been found to be double.

A Determination of the Cause of the Discrepancy between Measures of Spectrograms made with Violet to Left and with Violet to Right: H. M. Reese.

In this paper three possible causes of the effect in question are investigated: (1) The curvature of the spectral lines; (2) the position of the star-spectrum in the

middle of the plate, enclosed by the comparison-spectrum; (3) a mere subjective tendency to set the cross-hair relatively farther to the right on a dark line in a white field than on a bright line in a dark field. The conclusion is reached that the third cause alone really operates, or at least that neither the curvature of the lines nor the relative position of star-spectrum and comparison affect the case.

Four New Spectroscopic Binaries: W. W. CAMPBELL.

Four stars have recently been observed with the Mills spectrograph to have variable velocities in the line of sight. These are φ Persei, ξ Herculis, α Equulei and υ Andromedæ. The first of these is an interesting bright-line star. The second has a large radial velocity, and is moreover an interesting visual double star whose period is about 33 years. This therefore affords another connection between visual and spectroscopic binaries. In the case of the third star, a composite spectrum was observed a few years ago by Miss Maury at Harvard College Observatory. Thirty-two spectroscopic binaries discovered with the Mills spectrograph in the past three years had previously been announced, thus bringing the number up to 36. On the list of suspected binaries are 14 stars, awaiting confirmation. Before the discovery of these binaries, 3 had been found in the same list of stars by Belopolsky, making about 40 spectroscopic binaries in 325 stars observed. The proportion is therefore one spectroscopic binary for every eight stars observed. The variable velocity of our sun, due to its revolving planets, has a double amplitude of only a few hundredths of a kilometer. As the work progresses and the degree of accuracy attainable increases, we shall probably find that there is a regular gradation of double amplitudes from that of our sun up to those of the spectroscopic binaries already discovered, and it is possible that the star that is not a spectroscopic binary will prove to be the rare exception. This field of investigation is one of extreme richness.

Discovery of Five Hundred New Double Stars: W. J. HUSSEY.

While observing the Otto Struve double stars the writer discovered new companions to five of them and also picked up several new pairs in the vicinity of others. This led to the notion of making an extended search for new pairs, which was begun as soon as it was possible to do so without interfering with the work in progress. In the spring of 1899 search was commenced in a tentative way and in July of the same year it was taken up regularly, and since then has been conducted in a systematic manner. While only a part of the writer's time has been devoted to the consideration of new double stars, he has now discovered and measured five hundred new pairs having distances under five seconds. The work has been done with both the twelve- and thirty-six-inch telescopes of the Lick Observatory. Many close and difficult pairs, some of them having distances less than a quarter of a second, have been found with the smaller instrument, but nearly all the measures have been made with the great telescope. The classification of the new pairs with respect to the distances between their components is as follows:

0″.25 or less,	37 pairs,
0 .26 to 0″.50,	96 pairs,
0 .51 to 1 .00,	112 pairs,
1 .01 to 2 .00,	112 pairs,
2 .01 to 5 .00,	143 pairs.

Seventy-one per cent. of the total number have distances under two seconds; 49 per cent. under one second; 27 per cent. under half a second; and seven and one-half per cent. under quarter of a second.

On the Discovery of 300 Double Stars: R. G. AITKEN.

The writer's experience in observing double stars led him to conclude that it was desirable to make a systematic search for new pairs. As a contribution toward such a piece of work, 10,917 stars brighter than 9.1 magnitude have been examined by him since April, 1899, with the result that 301 new double stars have been found. These all have distances between their components of less than 5″.00, 217 or 72 per cent. being closer than 2″.00, and 19 closer than 0″.25. The search has been made mainly with the 12-inch telescope. The zones examined also contain 530 stars previously catalogued as double, but only 308 of these pairs are comparable with the new pairs with respect to the angular separation of their components. A new double star has been found for every 36 stars examined and one star in every 18 examined is double within the adopted limit. On this basis it is estimated that more than 3,000 close double stars, within the reach of the telescopes of the Lick Observatory, still await discovery.

A Kinematic Study of Hansen's Ideal Coordinates: KURT LAVES.

In the 'Auseinandersetzung' of Hansen the ideal coordinates are defined by the equations

$$\begin{aligned} X\frac{d\alpha}{dt}+Y\frac{d\beta}{dt}+Z\frac{d\gamma}{dt}&=0\\ X\frac{d\alpha'}{dt}+Y\frac{d\beta'}{dt}+Z\frac{d\gamma'}{dt}&=0\\ X\frac{d\alpha''}{dt}+Y\frac{d\beta''}{dt}+Z\frac{d\gamma''}{dt}&=0 \end{aligned}\qquad(1)$$

$\alpha, \beta, \gamma, \cdots \gamma''$ are functions of the time, the fixed coordinates xyz are connected with the movable coordinates X, Y, Z by means of the equations

$$\begin{aligned} x&=\alpha X+\beta Y+\gamma Z\\ y&=\alpha' X+\beta' y+\gamma' Z\\ z&=\alpha'' X+\beta'' Y+\gamma'' Z. \end{aligned}\qquad(2)$$

Hansen joins to the conditions (1) the condition:

$$Z=0 \qquad (3)$$

and obtains a well-defined system of ideal coordinates. Hansen has shown that the three homogeneous equations (1) lead to the following theorem: "In every ideal system of coordinates, referred to movable axes, the instantaneous axis of rotation coincides with the radius vector, drawn to the point." It is the intention of this paper to show that the last condition (3) will give rise to a kinematic theorem of similar import. Indeed, when we consider the three vectors, (1) the vector A of absolute acceleration of the point, (2) the vector of $A^{(r)}$ of relative acceleration of the point and (3) the vector $A^{(s)}$ of the acceleration of the movable system, we obtain for their components along the fixed axis three equations, of which only one is written down:

$$A_x=A_x^{(r)}+2\left(\frac{dX}{dt}\cdot\frac{d\alpha}{dt}+\frac{dY}{dt}\cdot\frac{d\beta}{dt}+\frac{dZ}{dt}\cdot\frac{d\gamma}{dt}\right)+A_x^{(s)} \qquad (4)$$

Calling the middle terms on the right sides

$$R_x, \quad R_y, \quad R_z$$

respectively, and projecting them upon the movable axis, we obtain

$$\begin{aligned} R_X&=-\frac{dY}{dt}\cdot r+\frac{dZ}{dt}\cdot q\\ R_Y&=-\frac{dZ}{dt}\cdot p+\frac{dX}{dt}\cdot r\\ R_Z&=-\frac{dX}{dt}\cdot q+\frac{dY}{dt}\cdot p \end{aligned}\qquad(5)$$

p, q, r having their usual meaning.

$$R=\sqrt{R_X^2+R_Y^2+R_Z^2}$$

will therefore be the moment of

$$\omega=\sqrt{p^2+q^2+r^2}$$

with respect to the point, which has for coordinates the quantities

$$\frac{dX}{dt}, \quad \frac{dY}{dt}, \quad \frac{dZ}{dt}.$$

Selecting the position of the XY plane to be that which coincides with the plane of this moment, we have two homogeneous equations of condition, namely,

$$-\frac{dY}{dt}r+\frac{dZ}{dt}\cdot q=0$$
$$-\frac{dZ}{dt}p+\frac{dX}{dt}\cdot r=0 \qquad (6)$$

it can be shown that these are equivalent to the one equation $Z=0$. We derive therefore the following: *Theorem.* The condition $Z=0$, which Hansen imposes upon his ideal coordinates, means that he selects for the XY plane the plane of the moment of the vector of instantaneous rotation with respect to the point of coordinates

$$\frac{dX}{dt},\ \frac{dY}{dt}.$$

The Computation of Laplace's Coefficients by Means of Gyldén's γ-coefficients: KURT LAVES.

In this paper it is shown, how the quantities $b^{(i)}$ and $c^{(i)}$ can be determined by means of the definite integrals $_s\beta^i$ tabulated by Gyldén in his Hülfstafeln (after multiplication with functions of the argument α). A comparison is made with the table of Runkle, formerly used for this purpose.

Astronomical Photography with the 40-inch Refractor and the Two-foot Reflector of the Yerkes Observatory (Illustrated with lantern slides): G. W. RITCHEY.

The 40-inch refractor, which was designed for visual observations, has been made available for photography through the use of a color screen and isochromatic plates. The greenish-yellow screen, placed in contact with a plate sensitized for light of this color, permits only those rays to pass for which the object glass is corrected. For all but the briefest exposures a double-slide plate-holder is employed. By means of two screws, which move the plate and guiding eye-piece, a star just outside the field being photographed is kept at the intersection of two spider lines throughout the exposure. In this way irregularities in the driving of the telescope, changes in refraction, etc., are corrected. The resulting photographs of the moon, Orion nebula, star clusters, etc., are exceedingly sharp, and are well adapted for measurement on account of their great scale. The two-foot reflector, on account of its short focal length (8 feet) and its freedom from chromatic aberration and absorption, is adapted for a different class of work, in which it admirably supplements the 40-inch refractor. All parts of this reflector were constructed at the Yerkes Observatory. On account of the perfect driving of the clock, permanence of collimation of the large mirror and freedom from flexure in the mounting, photographs of excellent definition are easily obtained. Among those exhibited were the Andromeda nebula, the Orion nebula, nebulæ in the Pleiades, and the expanding nebula surrounding *Nova Persei.*

A Remarkable Disturbance of the Sun's Reversing Layer: GEORGE E. HALE.

A series of photographs of the solar spectrum, taken at the Kenwood Observatory in February, 1894, shows that the reversing layer surrounding a sun-spot was the scene of a great disturbance, which lasted only a few minutes. The diameter of the disturbed area was not less than one-sixth that of the sun. Over this entire region the dark lines of the solar spectrum were for a short time so changed in appearance as to be wholly unrecognizable. Measurements of the photograph show that nearly all of these lines occur in the normal solar spectrum, and that the changed appearance is due to great changes of relative intensity. Thus numerous lines barely visible on Row-

land's map were for a short time very intense, while others, such as the aluminium line of intensity 20 at λ 3,961.674, disappeared entirely. Two sharp bright lines appeared at λ 3,884.67 and λ 3,896.21. These were strongest in the spot, and did not extend to the limits of the disturbed area. Full details will be published in the *Astrophysical Journal.*

The Bruce Spectrograph of the Yerkes Observatory: EDWIN B. FROST.

The equipment of the Yerkes Observatory has been recently enlarged by the completion of a spectrograph designed for the special purpose of the determination of the motion of the stars in the line of sight. The addition of this instrument to the accessories of the forty-inch telescope was made possible by the liberal gift of $2,300 from Miss Catharine W. Bruce and $500 from the Rumford Fund of the American Academy of Arts and Sciences. The spectrograph is very rigidly constructed, chiefly of iron and steel, and the prisms are maintained in a fixed, invariable position. The whole instrument is inclosed in a large aluminium case with double walls, for protection against changes of temperature. Coils of wire inside this case can be heated by the 110-volt current of the observatory mains, and it has been found not difficult to keep the temperature of the air in the prism-box within 0°.1 C. during exposures of an hour or more. A correcting lens placed one meter in front of the slit makes the visual forty-inch object-glass efficient for the violet light (λ 4,500) which passes through the prism-train at minimum deviation. The collimator is of 2 in. aperture and 38 in. focus; and two cameras are provided, one of 3 in. aperture and 24 in. focus and another, a Zeiss anastigmat, of about 2.8 in. aperture and 18 in. focus. The first three lenses are of triple construction, designed by Professor C. S. Hastings and made by Brashear. It has proved to be a matter of great difficulty to obtain prisms of the large size necessary to transmit a two-inch beam which are sufficiently homogeneous. (The face of the largest prism is 133 mm. long and 57 mm. high.) After an unsuccessful experience with a set of prisms of what appeared to be excellent glass from Mantois, a quantity of glass was ordered from Schott & Co., of Jena, which should be finely annealed and of the quality of telescope objectives, a requirement which, strangely enough, does not appear to be customary in respect to glass for prisms. This new set of prisms shows considerable improvement over the first ones. but the definition is still not the same over the whole surface of the faces. This is now assumed to be due to the moulding of the prisms in trangular shape at Jena instead of melting disks, as we had desired, from which the prisms would be cut by Brashear. Although the spectograph does not fully realize the resolution which the length of the faces of the prisms would imply, the instrument has nevertheless been shown to be capable of furnishing results of a very high degree of accuracy, as illustrated in the paper by an example of a plate of *α Arietis.* The comparison spectra so far employed have been the spark of titanium and of iron and the helium tube. During the exposure on a star the observer guides the telescope by light reflected from the speculum slit jaws, which are not in the same plane, but symmetrically inclined away from the line of collimation, each making with it an angle of 92° 55′. It is also possible, by merely turning a mirror, to observe in the same guiding telescope the light that has gone through the slit and has been reflected at the first surface of the first prism. The method of measuring and reducing the plates briefly described by the writer at the meeting of the Society in 1899 is still in regular use. Plates are measured

both with violet to right and with violet to left under the measuring miscroscope, as an observer may have a large systematic difference in his mode of making a setting on the dark lines of the comparison spectrum and the white lines of the stellar spectrum (on the negative). The writer has a large systematic error of this kind, which is reversed in sign but of the same size when the measures are made on a positive copy of the negative. By measuring the plate in both directions this systematic difference appears to be wholly eliminated. Each plate is reduced by itself, independently of any standard plate of a solar or metallic spectrum, with the aid of the Cornu-Hartmann formula in its simple form, the 'fit' of which can be checked up at the position of each comparison line and the wave-lengths corrected accordingly. The first star found by the Bruce spectrograph to be a spectroscopic binary is η Orionis. Four of the first plates, taken by Mr. W. S. Adams and the writer, yield the following velocities:

1901, Nov. 27,	—68	km.	per	second.
Dec. 6,	+13	"	"	"
Dec. 18,	+54	"	"	"
Dec. 19,	—56	"	"	"

The period is not yet determinate. In concluding the paper the proposal was made that the six or seven observatories, which now include in their work the determination of stellar velocities in the line of sight, should cooperate in regularly observing a short list of fundamental velocity stars. The comparison of the results obtained for the same stars with the different spectrographs and different observers, using different sources of comparison spectrum and different lines of the stellar spectra, could hardly fail to be of great value both in indicating causes of error in the separate instruments and in establishing with a high degree of accuracy the velocities of these fundamental stars. (To be published in *The Astrophysical Journal.*)

W. S. EICHELBERGER,
For the Council.

*THE RELATION OF THE AMERICAN SOCIETY OF NATURALISTS TO OTHER SCIENTIFIC SOCIETIES.**

I AGREE in general with all that has been said, and find myself in especially close accord with the remarks of Professor Trelease—so much so, indeed, that I might well refrain from saying more. Yet there are two points in the discussion to which I should like briefly to call attention.

We are all agreed that the object of our meetings is to spread the method and temper of science among the people—to inoculate the community with the spirit of science. Now, while the great central scientific meetings, so well described by Professor Minot, attract the attention of the whole country for a brief time, they do very little and can do very little in extending the influence or the real temper of science. This must be done, if at all, by the teaching, example and lives of those who are devoted to science, scattered through the country and making their influence felt daily throughout the year. It is, therefore, of the utmost importance that the local centers of science, and especially the smaller centers, remain vigorous. By these small centers I do not mean the great universities, or even the smaller colleges. The life of science in institutions of this character does not need the stimulus of meetings. Even at the present time men thoroughly trained in the methods of science are teaching in the normal schools and in the larger high schools throughout our country and the number of such teachers is rapidly increasing. One most im-

* Part of the discussion before the American Society of Naturalists received after the report had been published in the issue of SCIENCE for February 7.—ED.